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# Intelligent Bus Measurement and Control System Design Based on the TEDS

Cai Dongyang[a], Zhuo Zihan[a], Cao Xinrong[a], Tang Jintian*

*[a]Key Laboratory Particle & Radiation Imaging, Ministry of Education*
*Institute of Medical Physics and Engineering, Department of Engineering Physics, Tsinghua University*
*Beijing, China*

**Abstract**

The article describes in detail intelligent bus measurement and control system (IBS) which are based on CAN bus, Modbus communications protocols and Transducer Electronic Datasheet (TEDS). Measurement and control system are constituted by the host computer, nodes, and the bus. The host computer is the master node of the measurement and control system, realizing the control of salve node, the display of measurement results as well as interaction with the user. The slave node consists of the signal processing unit, the TEDS information storage unit, communication unit and an AVR microcontroller, for the measurement of physical variables, actuator control and data interaction. The system has been successfully applied to large-tumor magnetic induction therapy equipment, which is very stable and reliable.



"Keywords:TEDS; CAN bus; Modbus; IEEE 1451 standard"

## 1. Introduction

The development of modern science and technology has enabled the measurement and control technology to achieve digitalization, intellectualization and networked. Plenty of new network measurement and control

* Corresponding author. Tel.: +86-010-62796214;
*E-mail address:* tangjt@mail.tsinghua.edu.cn.

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systems are formed based on field bus technology and bus communication protocol. However, due to the different objects of measurement and control, when building measurement and control system, the engineer has to design interface circuit and modify the communication protocol tailored to specific objects, which costs the engineers to spend a lot of time and money to ensure compatibility.

In the field of sensors, in order to deal with the problem of a variety of objects interconnecting with a variety of network, the IEEE developed IEEE1451 interface standard to simplify the control network and connection, its main goal is to define a common set of communication interfaces, so that the transmitter can be independent of each kind of network. Fig.1 shows the architecture of the IEEE 1451 standard modules [1], which includes the Smart Transducer interface module (the STIM), a transducer independent the interface (the TII), and the network capability application processor (NCAP). The core technology of the STIM is TEDS [2][3][4], which has stored the module name, device type, serial number, calibration parameters and other information, so that the monitoring and control network has a certain ability to automatically identify the access object.

This paper has built an intelligent bus Measurement and Control system (IBS) based on TEDS, field bus and Modbus communication protocol. The system can realize the plug and play technique and automatic identification of the accessed control module and it has been successfully applied to the tumor magnetic induction therapy equipment, which is independently developed.

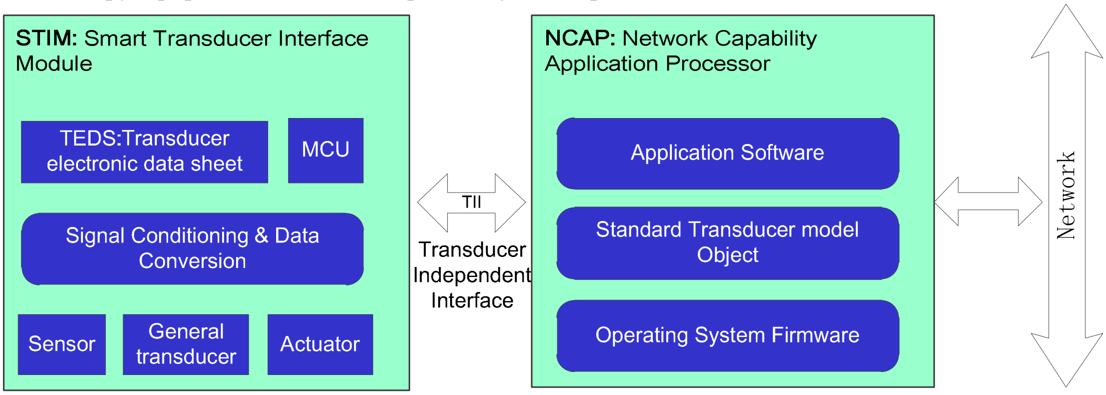


Fig.1 The architecture of the IEEE 1451 standard module

## 2. Proposed architecture

1451 standard divides the node function into two layers[5], the first layer is NCAP, which is used to run the network protocol stack and application firmware; second layer is the smart transmitter interface module, the STIM, including the transmitter and electronic data sheet, the TEDS. The industrial equipment measurement and control system usually use field buses, such as can bus and 485 bus, therefore in the specific application, the design of NCAP can be simplified, so that it only has data transmission, analytical and packaging functions, and may even integrate the NCAP to the STIM[6]. Fig.2 shows the basic architecture of a smart measurement and control module based on TEDS. It includes the following parts:

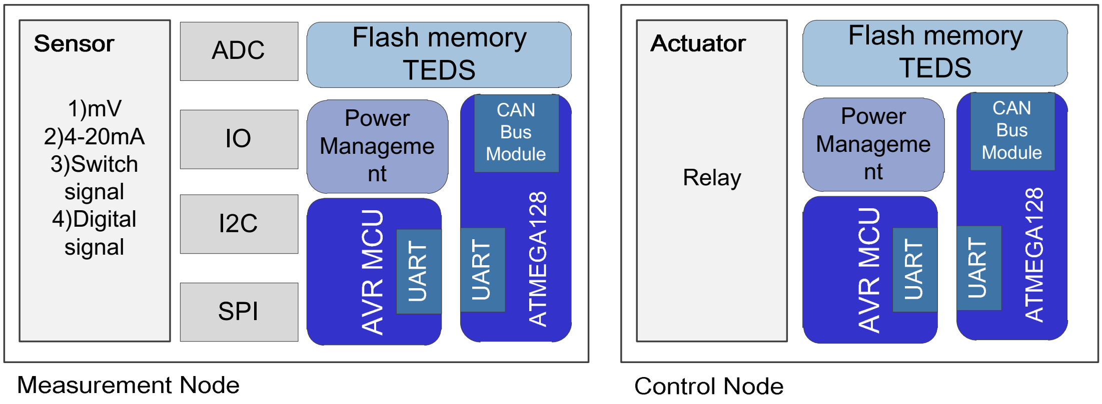


Fig.2 Basic architecture of IBS module

- STIM

In our architecture, it includes the physical sensors, actuator, signal conditioning, an AVR microcontroller unit with internal analog to digital converter, and the TEDS embedded in internal serial flash memory. The TEDS contains information about calibration, functionality parameters, vendor, data units, etc.

- NCAP

NCAP in our the design performs the connections between the STIM and the network, achieving the interaction of data between the STIM and the host computer, at its core is UART to CAN bus module, therefore the UART interface of the NCAP based on this paper will make it more convenient to transplant Modbus communication protocol[7][8].

- TEDS

Combined with the practical application, the intelligent modules developed have used four TEDS data field, that is meta-TEDS, Channel-TEDS, Calibration-TEDS, Meta identification TEDS. The information stored in the TEDS can be read and identified by the host computer through instruction, which is the core technology of IBS module plug and play technique and the automatic identification. Internal calibration unit can convert the measurement of current or voltage signals into the corresponding physical quantity and automatically correct according to the calibration engine, which improves the accuracy of the measurement results and simplifies the process of host-side data processing. The TEDS initialization software compiled by LabView write the initialization information of node through the bus interface in the MCU memory.

### *2.1. IBS Nodes*

Taking into account of the different objects, nodes have multiple types, including the mV voltage signal acquisition node, 4-20mA current signal acquisition node, switch acquisition node, single-bus data acquisition node, I2C bus acquisition node, relay output control node. All nodes are powered through the bus. The nodes internal circuitry includes signal conditioning unit, AVR microcontroller and power management. Each access network node has its own address, used to retrieve the node in the host computer. The node address is defined in Table 1.

Table 1 Address definition of Nodes

| Global Address | Node Address | Reserved Address |
|---|---|---|

| | | |
|---|---|---|
| 0x00 | 1-127 | 128-255 |

*2.2. Simplified NCAP*

The NCAP is integrated internally with an ATMEGA128 microcontroller and UART to CAN bus module. Microcontroller realizes the interaction of nodes and bus data through two serial ports. The MCU internal flash space stores the bus communication function code, on one hand MCU resolves bus instruction, forwards the host request to the STIM module, on the other hand, STIM data is packaged in accordance with the way that the host can resolve.

**3. Bus Communication Protocol**

Refer to the bus communication workflow of intelligent bus measurement and control system in Fig. 3. The host conducts timed polling to the slave, only when detecting a system exception of the slave, can the slave break the polling work style and directly send the host the total packet data. This way of working is real-time; the host can receive timely feedback in device failure to prevent accidents. Communication instruction is divided into global instruction and local instruction. Each instruction includes a simple protocol data unit (PDU) and application data unit (ADU) which is formed with the introduction of some additional domain in the data unit. Instruction uses RTU protocol of the Modbus communications to transmit, and the CRC to calibrate, with no start and end tags [9].

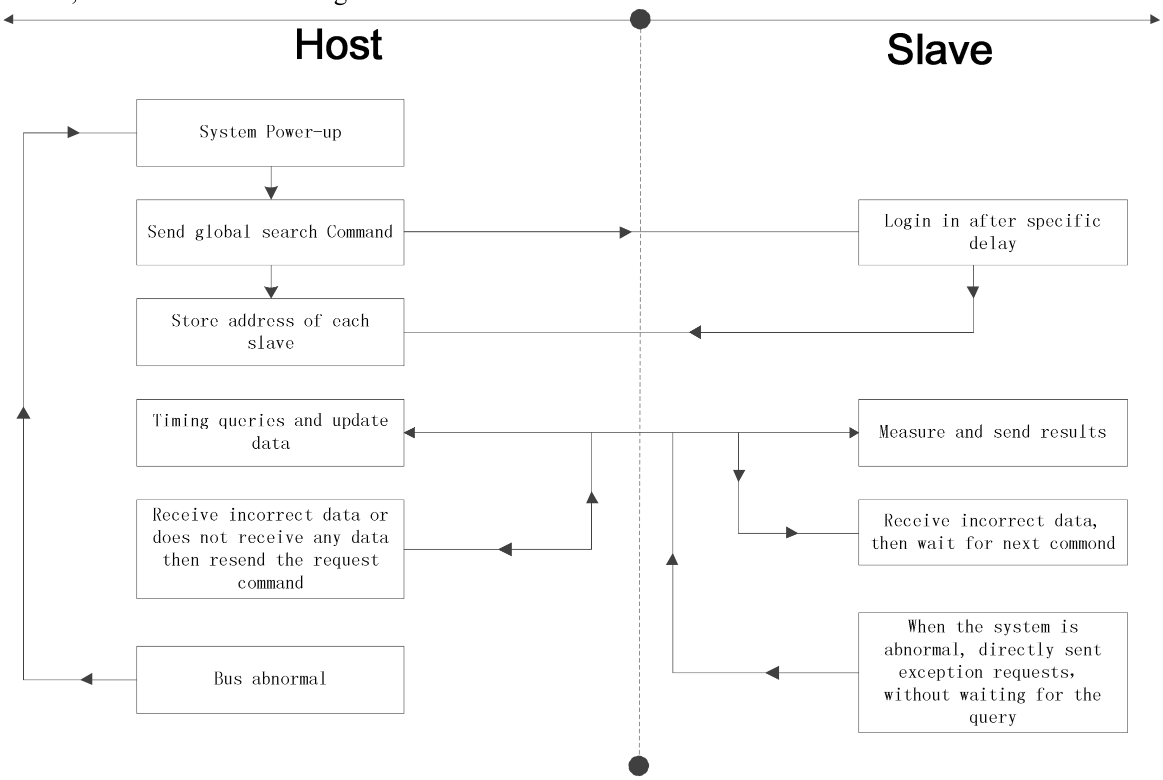


Fig.3 Bus communication process

During the data request - response process, there are two exceptions: the transmission of data errors, which is showed as the data cannot pass the calibration; there is no data response after waiting for the end of the response time. When an exception occurs, the host needs to re-request data, if the bus has no data response after a long time, it may be the bus exception. Once the bus has an exception, the host side has to restart the bus power, and then reset all nodes. At the same time, the CAN bus possesses good exception handling mechanism, which can greatly reduce the possibility of bus exception from the physical level.

## 4. IBS for Magnetic Induction Therapy Equipment

Magnetic induction therapy equipment is a new type of equipment used in tumor therapy, the equipment heats implanted ferromagnetic thermal seed by high-intensity alternating magnetic field in the coil so as to realize the targeted tumor hyperthermia[11][12]. Measurement and control system in Fig.4 mainly monitors the following parameters: the cooling water flow, using the flow transmitter and the output is 4-20mA current signal; temperature of cooling water, using a digital temperature sensor DS18B20; water pressure, using diffused silicon pressure transmitter and the output is 4-20mA current signal; coil current, using a current transformer, the output current signal using one ohm constantan sample resistor to convert to 0-5V AC voltage signal; capacitor bank voltage, using the step-down transformer, and the output is AC voltage signal. After rectifier circuit, the DC voltage signal is collected by the microcontroller’s internal AD. Measurement data are converted in accordance with the correction model of TEDS internal definition and the final results are passed to the host computer through the nodes within the NCAP. 10-inch touch LCD are used for data display and user interaction. The device are tested when turning on, and is proved that the can bus can work stably for a long time in the case of the internal electromagnetic interference.

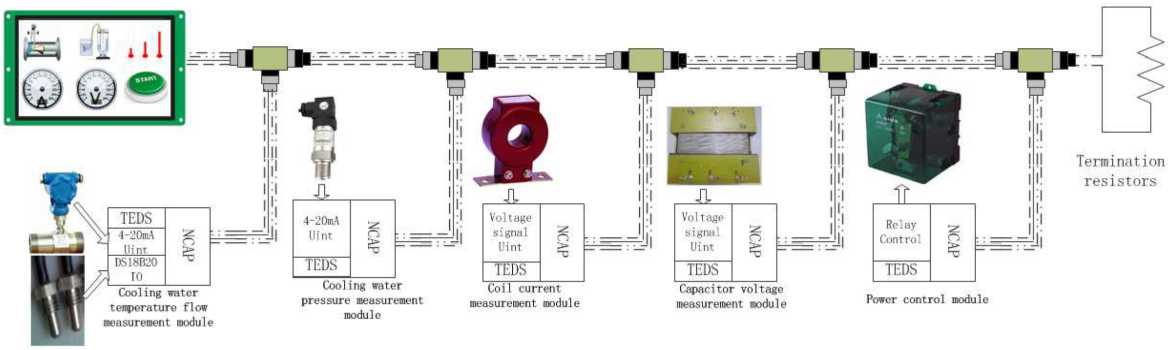


Fig.4 Intelligent bus control system for magnetic induction therapy equipment

## 5. Summary

This article describes an intelligent bus measurement and control system design with a simplified TEDS. TEDS stored the basic information about node in a generic way, and allows the self-identification of the sensors and actuators to the networks and systems. Digital communication interface transmits the standard TEDS reading and writing instruction on the CAN bus in accordance with the Modbus communication protocol format. This allows all nodes based on TEDS and the standard reading and writing commands can be read by hosts running the same protocol. The microcontroller coming with the NCAP can complete communication protocol parsing and packaging, enabling system development not to consider the complexity of the bus communication protocol, and reduces the technical threshold of using TEDS to develop the intelligent control node. For a variety of signals, such as the transmitter output 4-20mA signal, AC and DC voltage signal, different signal conditioning circuits have been designed, each circuit as a separate module. Plenty of signal conditioning modules and transparent data transfer module, unified data storage, the standard transfer protocol enables the control node constructed in the modular way. By using this design method, it will reduce the product development cycle, and makes it easier to maintain and upgrade. Finally, because of the use of standardized components and the communication interfaces, interoperability is no longer an issue.

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